Fuzzy Logic Approach for Impact Source Identification in Ceramic Plates

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Outline

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Introduction

- Non-Destructive Techniques (NDT).
  - Detection, evaluation and locating cracks
  - Impact source identification
- Fuzzy logic : NDT applications
- Mamdani Fuzzy Inference System (FIS) using the Fuzzy Logic Toolbox.

Introduction

- A ceramic plate with 16 sections
- Generate waveforms analysis.
- FIS is used to identify Impact Source.
- RMS values, Mean, Median, Mode, Peak Value & FFT value.
- These outputs are inputs to FIS.
- Procedure to get output is discussed.

Test System Description and Methodology

- Problem to determine source of impact.
- Constraints:
  - An electric impact hammer.
  - The device hit the impacted surface.
  - Variable: material used for (Steel and Delrin®.)

Test System Description and Methodology

- Different impacting materials will generate different impact acoustic waves.

- The variables like RMS, mean, median, mode, peak value and FFT value used as parameters to differentiate input.

Fuzzy Impact Source Identification Approach on Real Time System

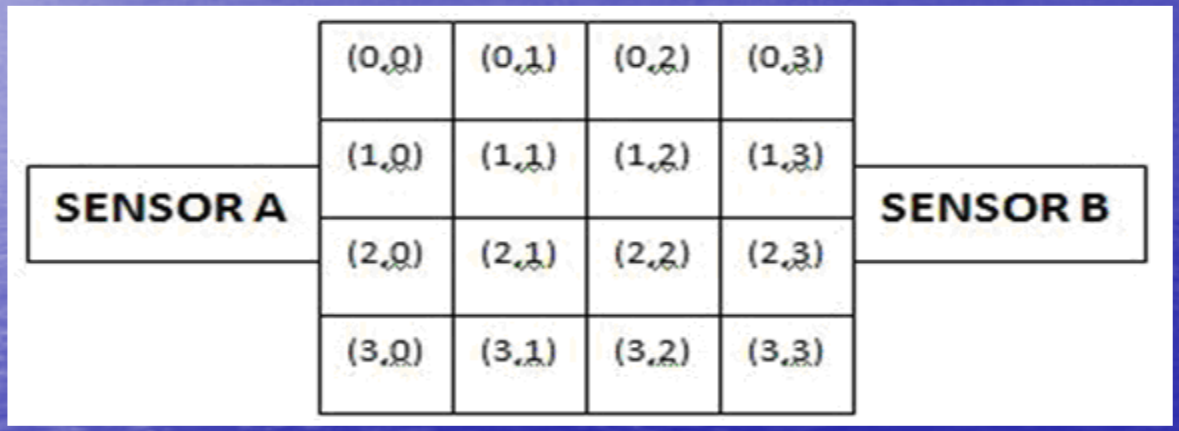

Fig. 1: Test System Circuit: Two Sensor Arrangement of the ceramic plate (courtesy of [1])

Test System Description and Methodology

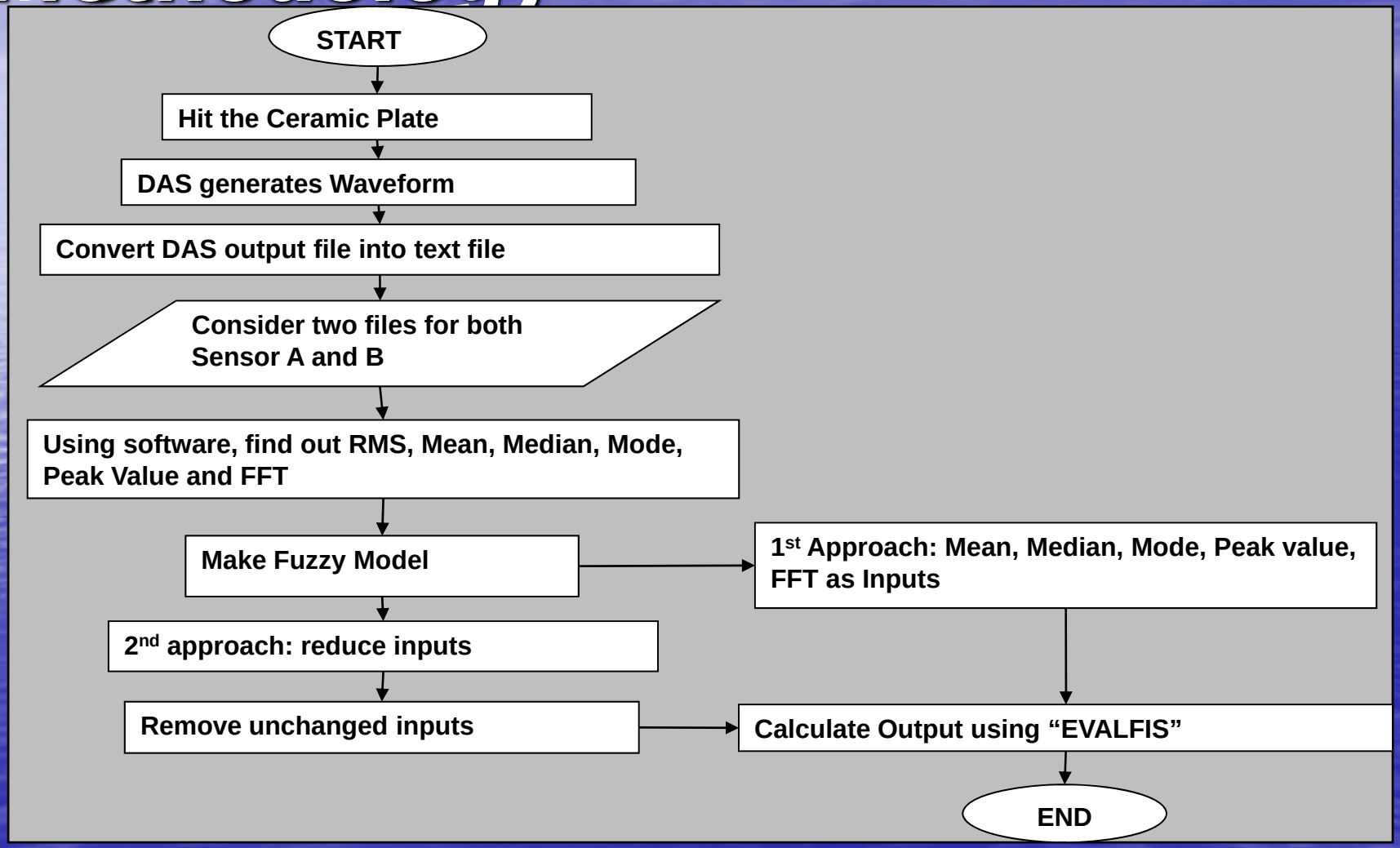

Fig. 2: Flowchart for Impact Source identification

Test System Description and Methodology

The impact source identification method:

- Consider two sensor arrangements
- Hit the surface with 1 of 2 defined source.
- DAS acquires waveforms 2 waveforms from sensors A and B, respectively.
- Obtain RMS value, Mean, Median, Mode, Peak value & FFT value from data.
- Define fuzzy model using Mamdani type FIS.

Test System Description and Methodology

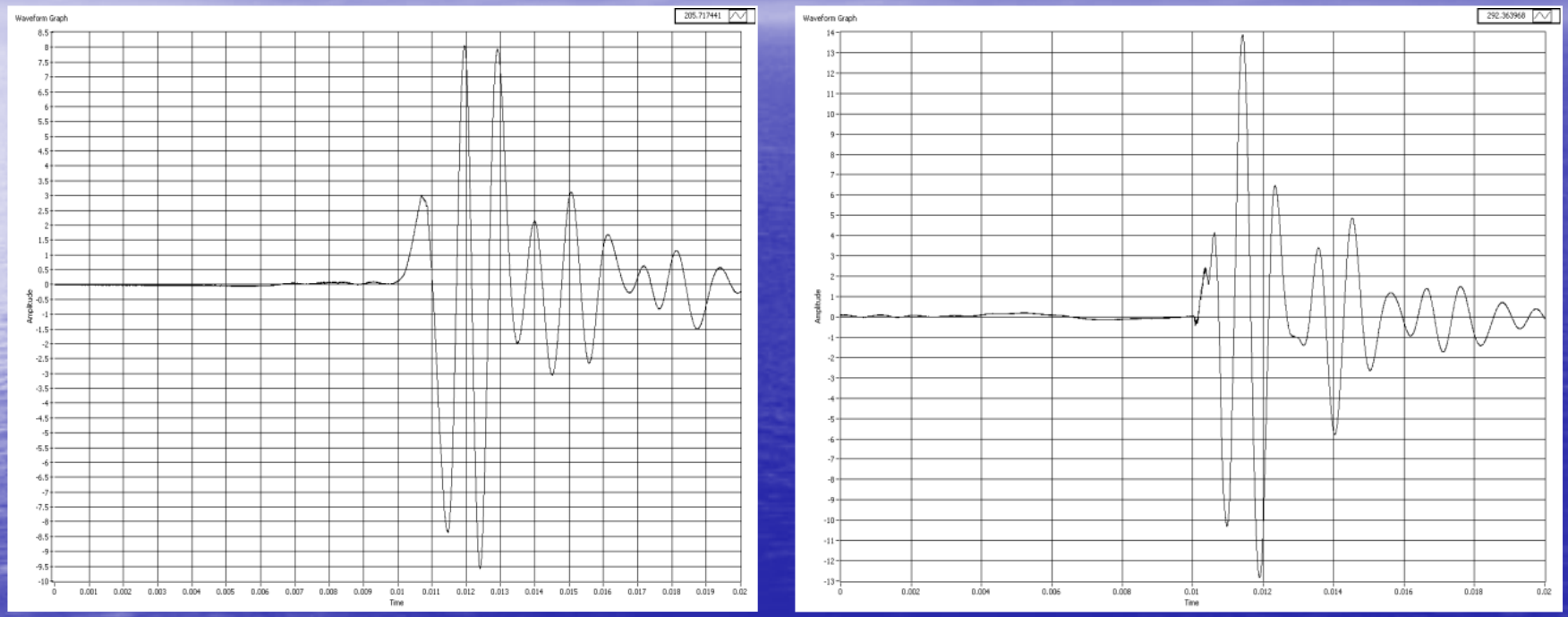

Fig.3 Sample waveforms obtained after creating Impact from Delrin® on left and Steel on right on section(0,2)

Table 2: Range Defined for Inputs

	LL	LH	ML	MM	MH	HL	HH
Arms	0.1 – 1.1	1.1 - 1.4	1.4 – 1.7	1.7 – 1.9	1.9 – 2.3	2.3 – 3.5	3.5 - 4
Amax	0 - 6.5	--	6.5 – 8	--	8 – 10	--	10 - 18
Brms	0 – 1.5	1.5 – 2.4	2.4 – 2.9	--	2.9 – 3.3	--	3.3 - 5
Bmax	0 – 10	--	10 – 13	--	13 – 15.4	--	15.4 - 18

Fuzzy Impact Source Identification Approach on Real Time System

- Real time parameters: RMS value, Peak value, Median, Mode and FFT value.
- Unique 5 FIS parameters: Location Index, Arms, Amax, Brms & Bmax
- The parameters ranges in Table 2.
- FIS output value around 0.25 corresponds to Delrin® & 0.75 to Steel

Fuzzy Impact Source Identification Approach on Real Time System

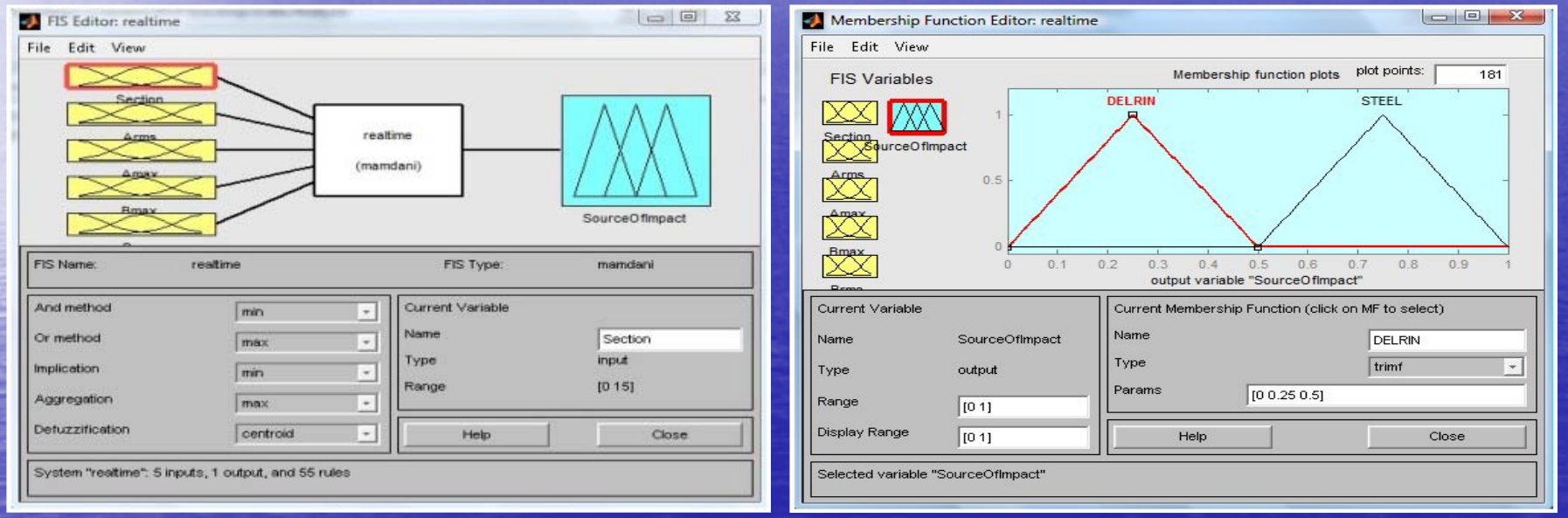

Fig. 4 Fuzzy Inference System: (a) five Inputs, (b) Output membership function

Fuzzy Impact Source Identification Approach on Real Time System

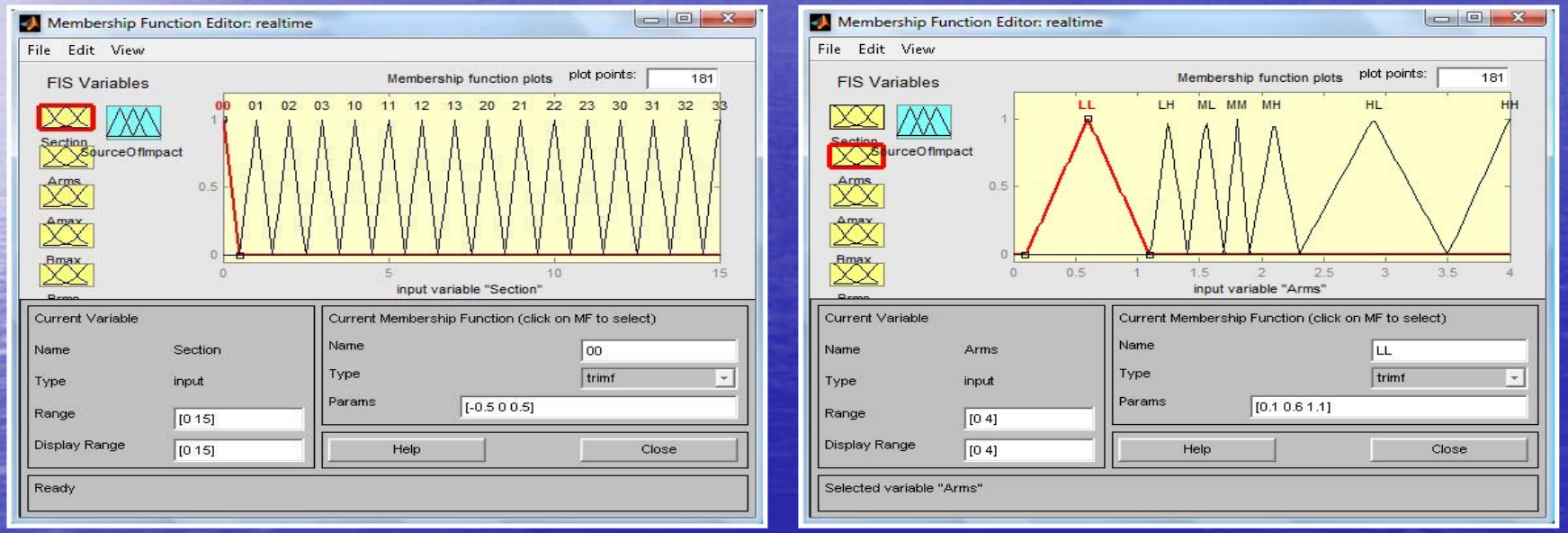

Fig. 4 Fuzzy Inference System: (c, d) Input membership function

Fuzzy Impact Source Identification Approach on Real Time System

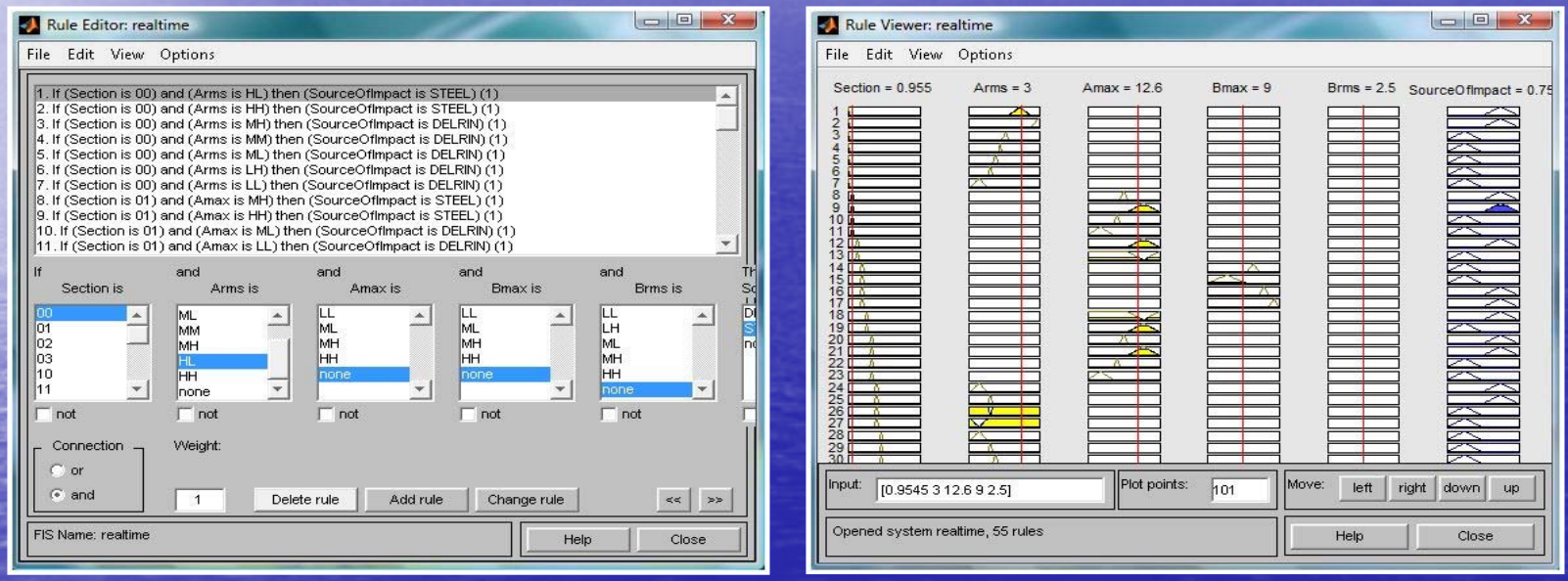

Fig. 4 Fuzzy Inference System: (e) Rule Editor, (f) Rule Viewer

Appendix Table 1: Data File for captured Impact Waveforms

INDEX	A-RMS	A-MEAN	A-MEDIAN	A-MODE	A-MAX	A-FFT	B-RMS	B-MEAN	B-MEDIAN	B-MODE	B-MAX	B-FFT	OUTPUT
(0,0)	2.853457	-0.14467	-0.20569	0.089661	17.63706	0.550063	2.232264	0.070128	0.0966	-0.23224	11.12996	-0.5005	Steel
(0,0)	2.12684	-0.04041	0.402387	-1.36973	10.24457	0.506629	1.197423	0.035839	-0.15435	-0.11974	5.262808	-0.50915	Delrin®
(0,1)	2.625784	-0.10151	0.098347	0.506629	14.74435	0.506629	2.556979	-0.02271	-0.06782	-0.76011	12.49723	-0.5005	Steel
(0,1)	1.90866	-0.03329	0.358952	0.367639	8.611444	0.506629	2.448746	0.016999	0.243712	0.001411	9.304045	0.50332	Delrin®
(0,2)	2.786107	-0.09544	0.202589	0.402387	16.05606	0.506629	2.995505	-0.05068	0.113908	-17.6866	10.78381	0.537935	Steel
(0,2)	1.854013	-0.03527	0.367639	0.367639	8.029426	0.515315	2.875283	0.035245	0.451399	-0.68223	8.101193	0.50332	Delrin®
(0,3)	2.703809	-0.04608	-0.0059	0.689052	15.73465	-0.52711	3.831043	0.381775	0.131215	-17.6866	17.74997	0.520628	Steel
(0,3)	2.110172	-0.01396	-0.44024	-1.1873	12.96355	-0.50104	3.070854	0.11412	0.312941	-17.6866	9.529039	0.511974	Delrin®
(1,0)	2.005689	-0.09951	0.072287	-0.55317	8.342152	-0.50104	2.187488	-0.01156	-0.11109	-0.73415	9.892491	0.537935	Steel
(1,0)	2.874385	-0.02179	0.133095	0.020166	9.888408	0.506629	1.603892	0.012873	-0.26685	-0.82934	8.300226	-0.5005	Delrin®
(1,1)	1.676259	-0.04012	-0.04064	0.3937	8.724373	-0.50104	1.573216	-0.0493	-0.02455	0.511974	6.34451	-0.5005	Steel
(1,1)	2.009339	-0.06173	0.028853	0.202589	6.830643	-0.50973	1.532659	-0.05534	-0.11109	-0.48319	8.568488	-0.50915	Delrin®
(1,2)	1.364033	-0.22585	-0.05802	-0.15357	4.832671	0.654305	2.122266	-0.10742	-0.06782	0.840811	9.174241	-0.5005	Steel
(1,2)	1.409268	0.04077	-0.10145	-0.62266	5.866405	-0.50973	2.107622	0.023921	0.105254	0.235058	8.040618	-0.5005	Delrin®
(1,3)	1.84302	-0.02824	-0.07539	-0.07539	10.27063	0.506629	2.782996	-0.12632	-0.11109	-0.46588	10.46363	-0.5005	Steel
(1,3)	1.506111	0.009663	-0.10145	-0.10145	7.681953	-0.50973	3.466485	0.095551	0.312941	0.581203	9.399235	0.50332	Delrin®
(2,0)	3.196053	-0.11055	-0.04064	-0.30993	17.02899	-0.50104	3.197639	0.013569	0.018718	-0.76876	17.08364	0.511974	Steel
(2,0)	4.061507	0.308466	0.219963	-17.7097	15.52616	0.506629	2.745315	-0.04166	-0.36204	1.559061	13.04241	-0.5005	Delrin®
(2,1)	2.037907	0.004193	0.167842	-0.9267	8.038113	-0.51842	1.761954	-0.08027	-0.11974	-0.12839	9.191549	0.650432	Steel
(2,1)	2.866071	0.050799	0.107034	-0.67478	11.7387	-0.50104	1.23982	-0.00197	-0.0332	-0.18032	5.574338	-0.5005	Delrin®
(2,2)	1.214743	0.009582	0.03754	0.054913	5.258326	0.515315	2.696384	-0.07744	-0.13705	0.442745	14.13276	-0.5005	Steel

Conclusion

- The Fuzzy Logic for impact source identification.
- Software implementation.
- Experiment on limited data
- FIS identifies Steel or Delrin® sources of impact.
- Future work will involve more data & identification of more impact sources.
- Approach suggested here will lead to more reliable techniques.

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Thank You!